DesignBuilder scripting tools: Unlock almost unlimited flexibility to customise simulation behaviour

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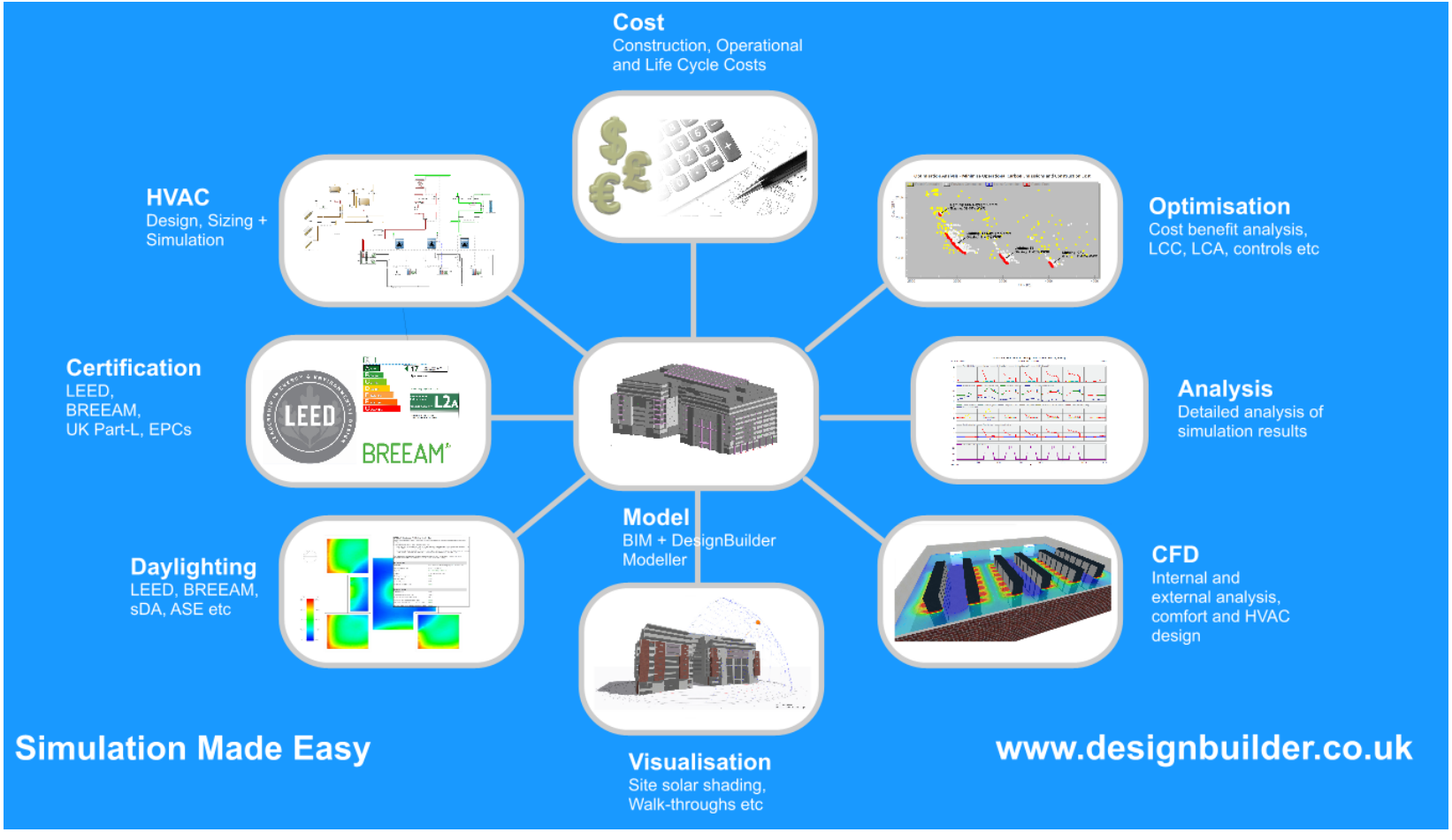
“Hacking Simulation” presentation content

- Introduce DesignBuilder’s scripting tools…what they are and how they can help.
- Simple example to illustrate how DesignBuilder’s scripting tools work in practise.
- Case studies showing how scripting has been used to customise simulated behaviour to meet non-standard or unusual client needs.

“Simulation Made Easy”…early, compliance or detailed modelling!

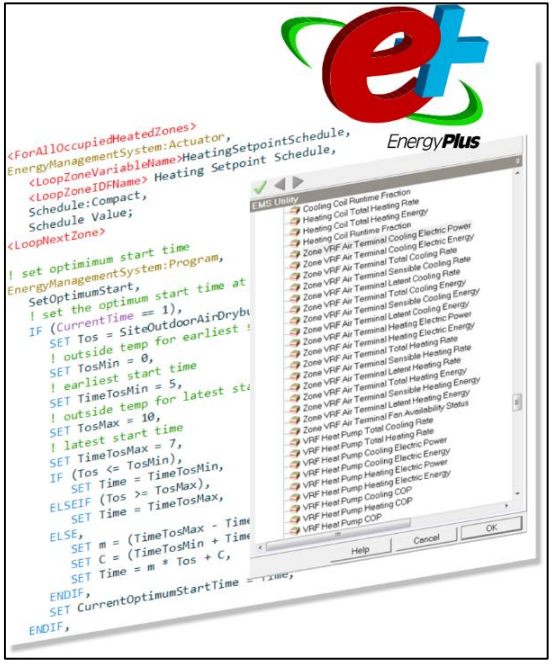
Engineers, Architects, Energy Assessors, Academic Research and Teaching



4 ways to “hack” DesignBuilder EnergyPlus simulations

“Regular” Modellers:

- Modify (open source) EnergyPlus input data file (**IDF)**
- **EMS** – Create/edit scripts in the DesignBuilder EMS editor



Experts:

- **FMU** – Create co-simulation applications in the DesignBuilder FMU/FMI editor
- Modify **EnergyPlus open source code**

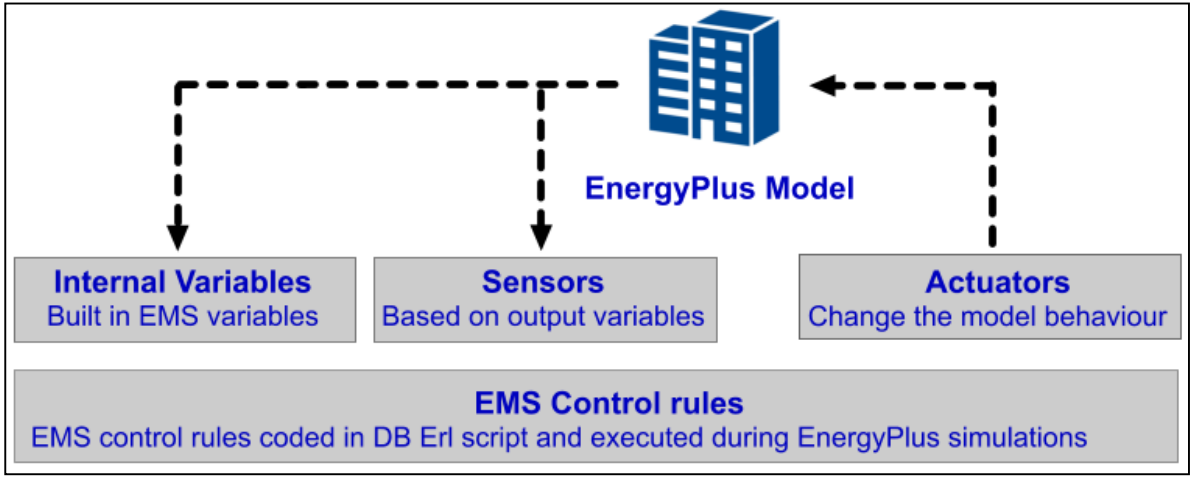
DesignBuilder EMS overview

1. Customise…add functionality not available in EnergyPlus
2. Overwrite standard controls with bespoke project logic
3. Dynamically adjusts behaviour during the simulation
4. Provides almost limitless range of additional functionality

5. EMS scripts pre-compiled…no noticeable impact on simulation times
6. Load existing library EMS programs or create (and share) own scripts
7. Relatively easily to learn and practical for use on commercial modelling projects…not just academic

DesignBuilder EMS: works like a BMS

1. **Sensors:** check variable value (zone air temperature, CO2 level etc.)
2. **Actuators:** overrides model settings based on sensor input to change the model behaviour at each time-step in the simulation.
3. **Results:** Custom output variables can be written to results file.
4. **Program:** manages and initiates what is called and at what frequency



Some example DesignBuilder scripting applications

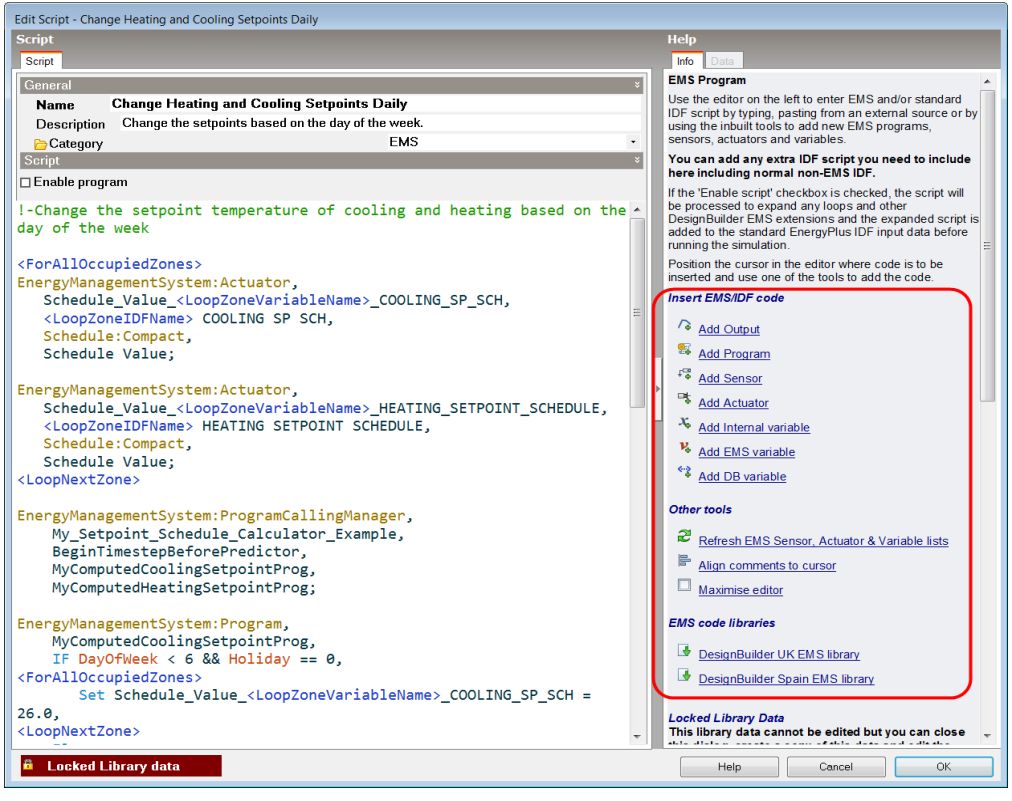
Flexibility to influence EnergyPlus simulation behaviour at each time-step using the EMS…almost limitless applications:

- Programmatic scheduling (over-ride fixed/static schedules)
- Bespoke control of HVAC systems
- Connecting different HVAC systems
- Advanced façade and natvent controls
- Outputs not normally provided in DesignBuilder or EnergyPlus
- Research…novel applications not provided by mainstream tools

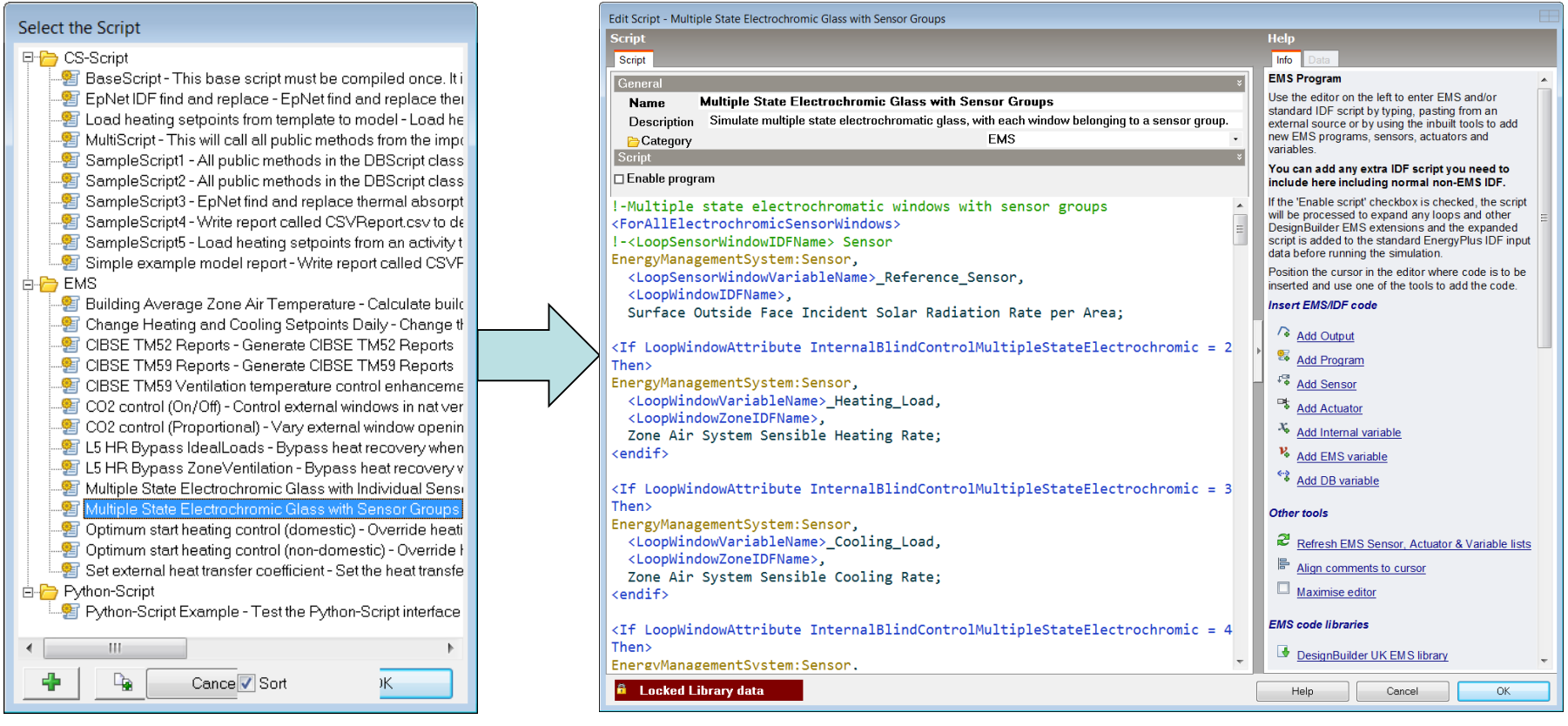
DesignBuilder EMS extensions…beyond EnergyPlus

DesignBuilder includes important extensions to the standard EnergyPlus EMS system to **simplify and speed up script generation**:

- Access attribute data (setpoints, schedules etc.) direct from model data lists
- Quickly add actuators, sensors and internal variables
- Loops simplify scripts and make them portable
- Colour syntax highlighting

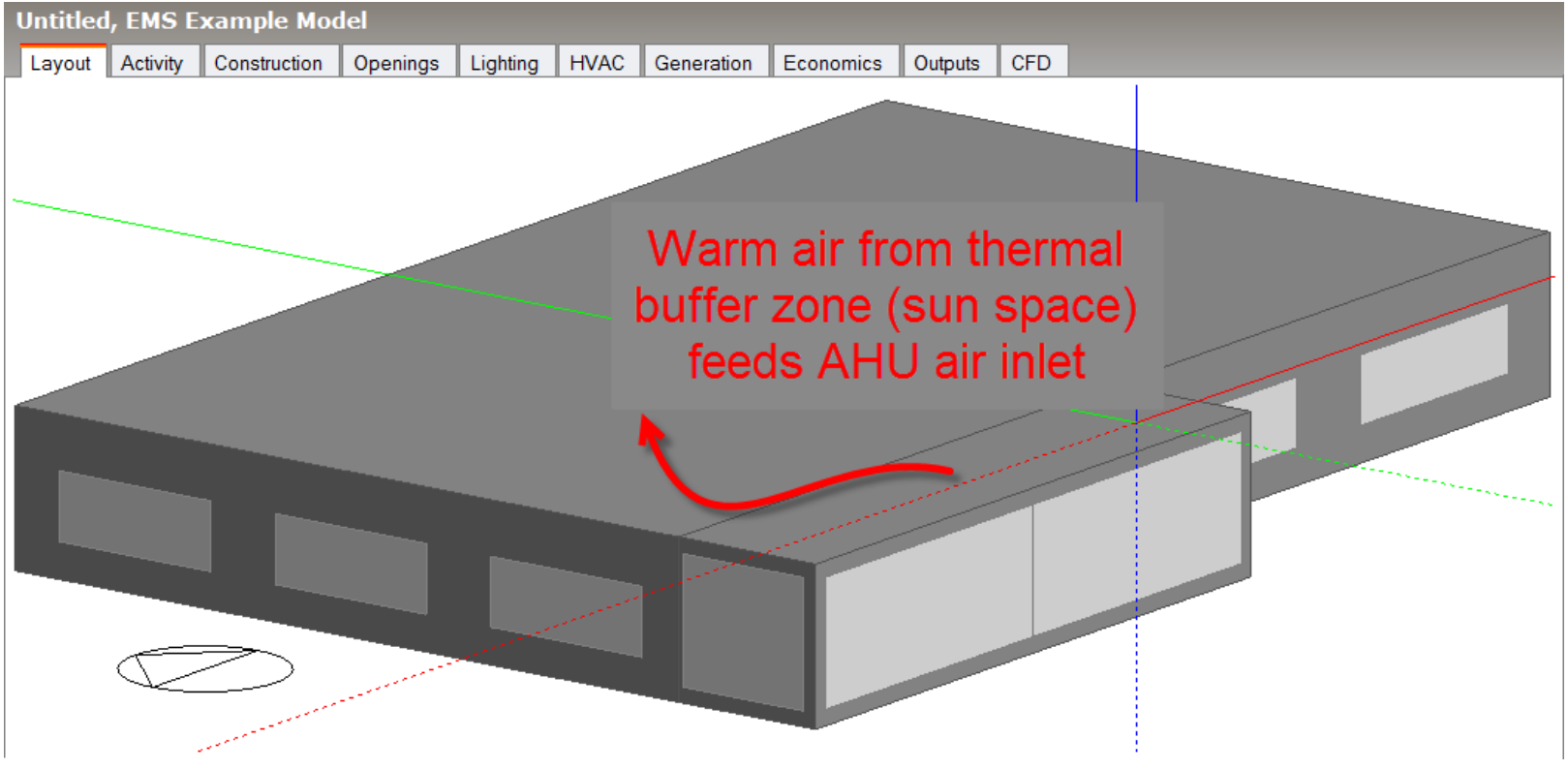


DesignBuilder's example script library



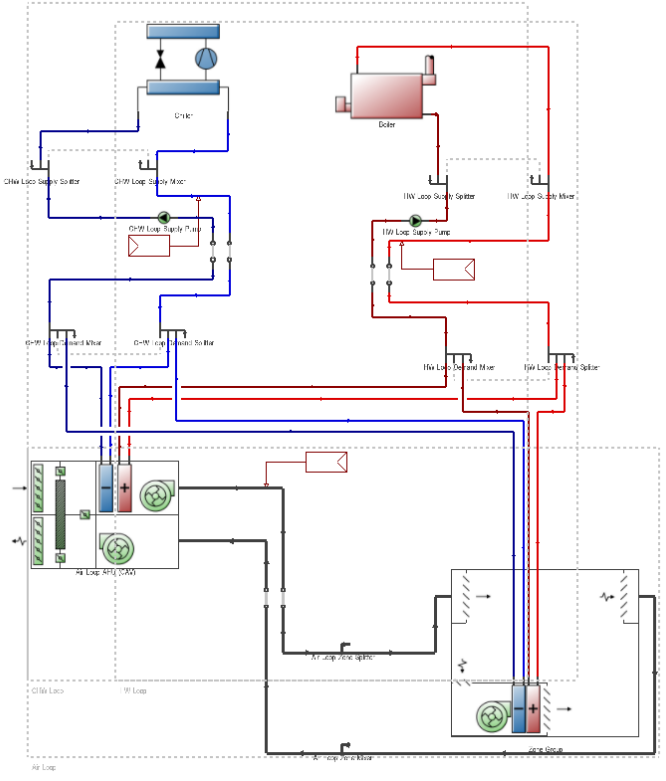
Simple AHU pre-heat example

Pre-heat or pre-cool AHU inlet air from sun space, earth tube etc



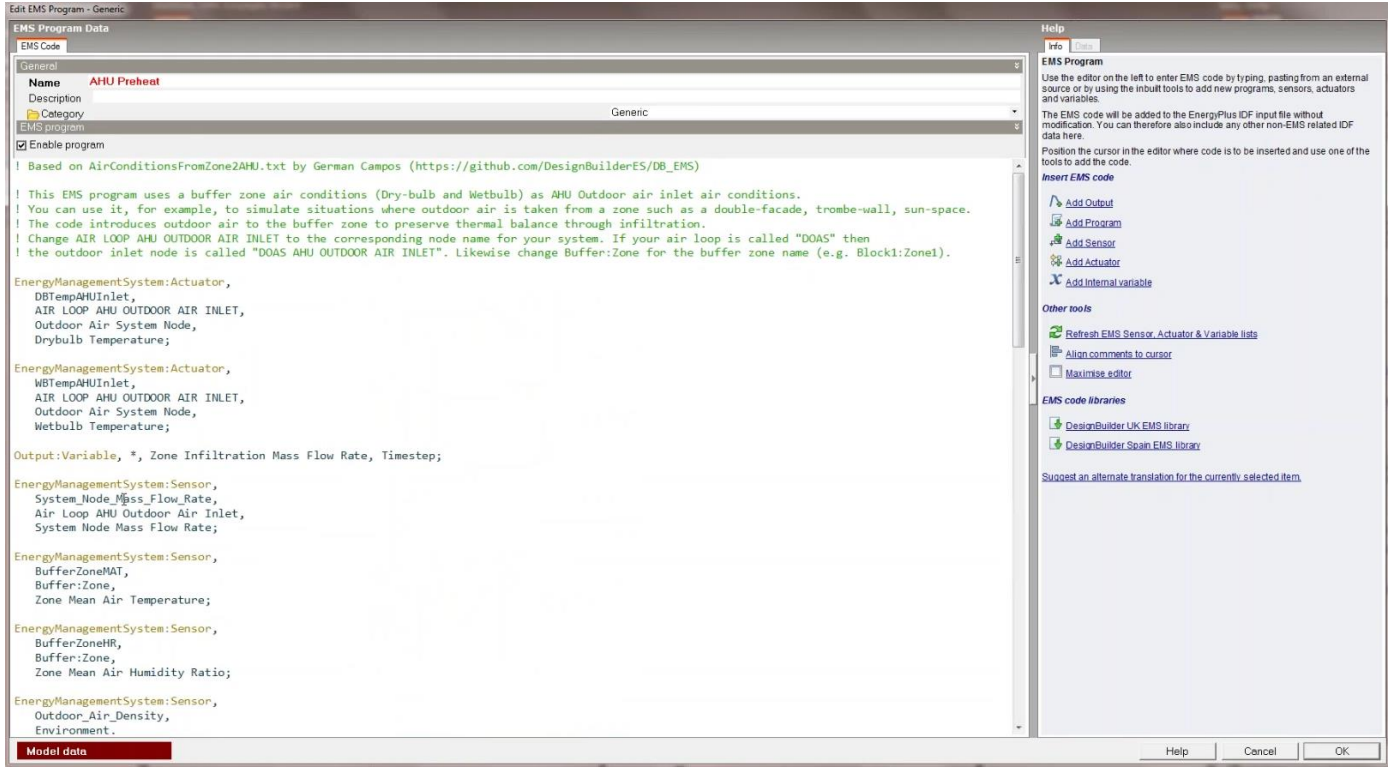
Simple AHU example…HVAC system

Zone FCUs served by AHU with CHW and HW coils…but **no AHU pre-heat**



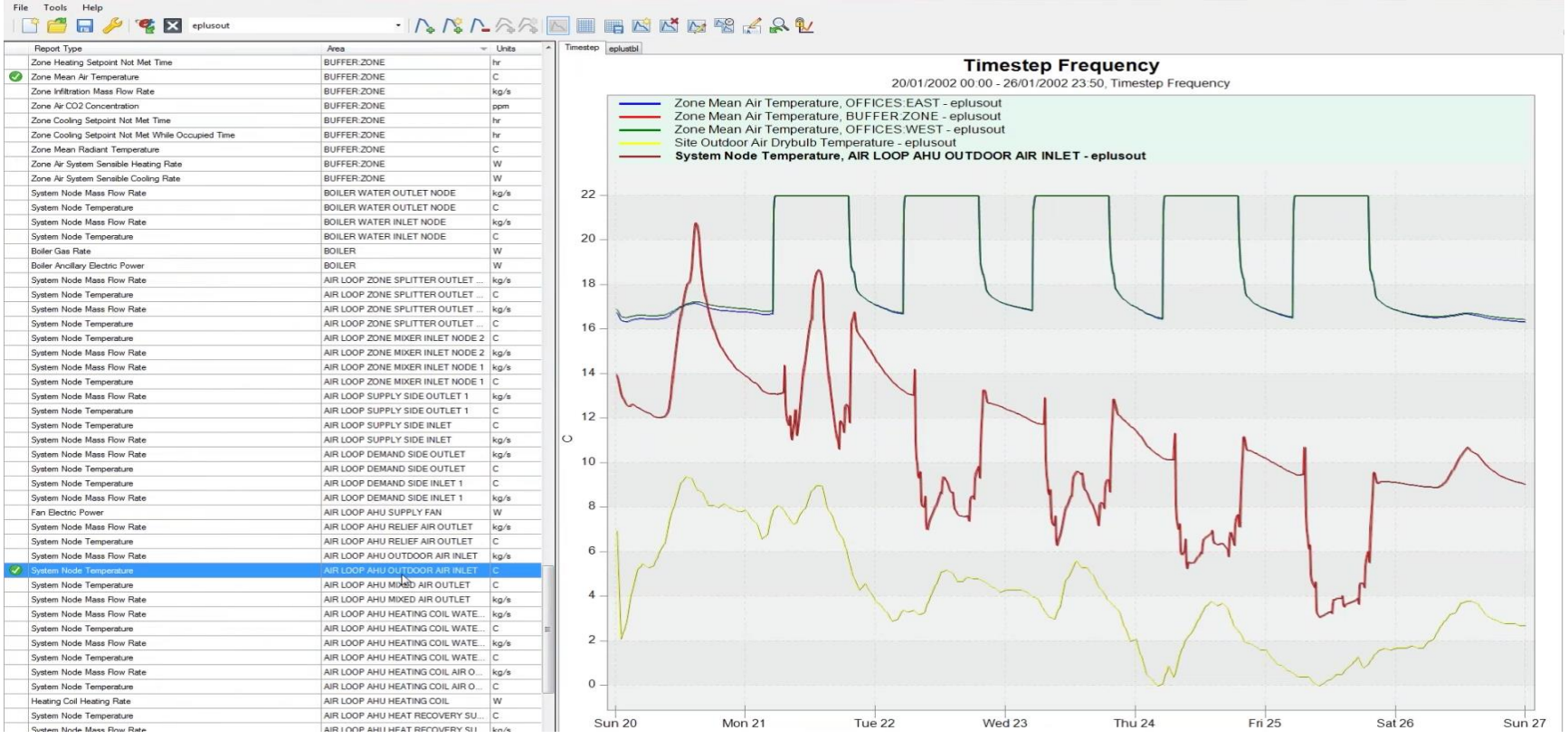
Simple AHU pre-heat example…script

Script links pre-heat zone air to AHU inlet to over-ride standard HVAC setup



Simple AHU pre-heat example…results

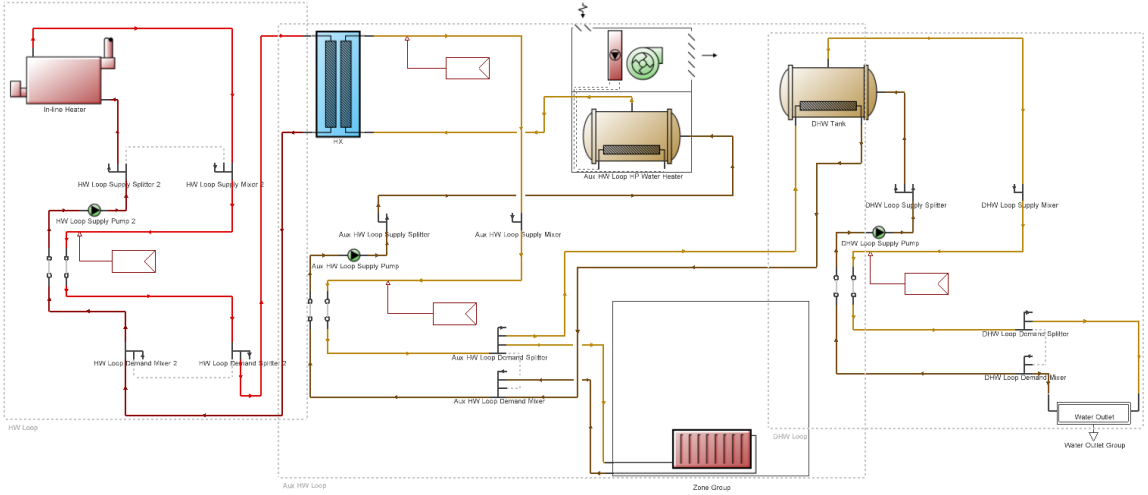
Results show that the AHU air inlet temperature matches buffer zone (not OAT)



Hybrid ASHP - EMS case study

(Project with Delta-ee and Dr Dave Kane)

Range of LT/HT/Hybrid ASHP systems modelled for different dwelling types.



- Specific manufacturers systems modelled in detail using EMS to provide:
  - Weather compensation controls for HW supply temperature
  - Tailored optimum start for both morning and evening heating periods
  - Custom control over electric boost availability to maximise efficiency

Hybrid ASHP – Example part of EMS script

- Weather compensation script to replace simple ASHP supply temperature schedule, accounting for DHW operation.
- Script minimises the HP supply temperature unless the DHW system is operating or outdoor temperature drops.
- This part of the EMS script is a good example of using SET, IF and ELSE statements to dynamically control equipment based on other variables

```
! override "ASHP outlet setpoint temperature" schedule with weather compensation
EnergyManagementSystem:Program,
   SetASHPSuppyTempSp,
   SET Tos = Site_Outdoor_Air_Drybulb_Temperature,
   ! outside temp for max setpoint
   SET TosMin = 0,
   ! max setpoint
   SET TspTosMin = 55,
   ! outside temp for min setpoint
   SET TosMax = 15,
   ! min setpoint
   SET TspTosMax = 40,
   ! set setpoint based on outside air temperature and DHW operation
   IF (DHWTankSourceSideHeatTransferRate > 10),
      ! use high temperature output when DHW is operating
      SET Tsp = TspTosMin,
   ELSEIF (Tos <= TosMin),
      ! very code outside, use highest supply temperature
      SET Tsp = TspTosMin,
   ELSEIF (Tos >= TosMax),
      ! warm outside, use lowest supply temperature
      SET Tsp = TspTosMax,
   ELSE,
      ! interpolate
      SET m = (TspTosMax - TspTosMin) / (TosMax - TosMin),
      SET C = (TspTosMin + TspTosMax - m * (TosMin + TosMax)) / 2,
      SET Tsp = m * Tos + C,
   ENDIF,
   ! actuate the supply setpoint temperature
   SET ASHPSuppyTempSp = Tsp;
```

UCL IEDE Case Study: ‘Total Performance’

Project to investigate ‘total performance’: finding ways to minimise energy demand and carbon emissions **whilst safeguarding occupant health, wellbeing and productivity**

Acknowledgements:

UCL IEDE:

Nishesh Jain, Esfand Burman, Sam Stamp, Clive Shrubsole, Dejan Mumovic, Michael Davies

DesignBuilder:

Andy Tindale

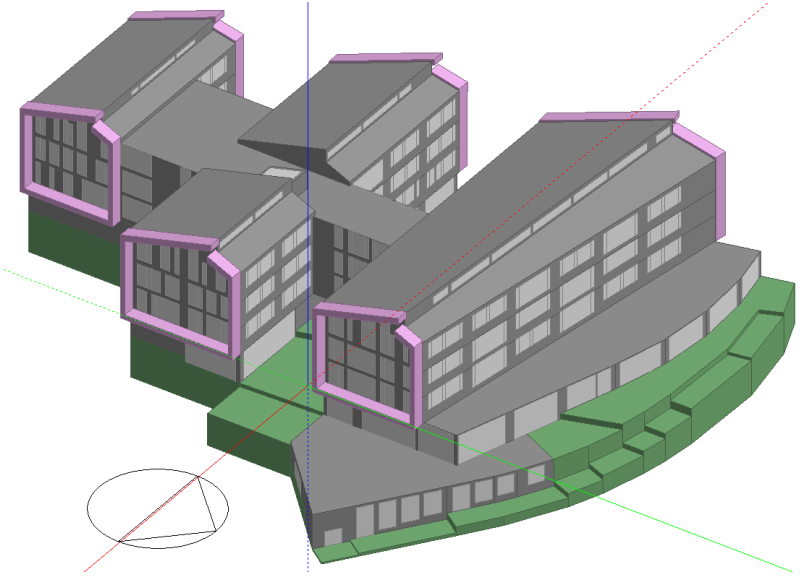
More information: www.ucl.ac.uk/bartlett/environmental-design/research/total-performance-low-carbon

UCL IEDE case study building

Public sector natvent open-plan office building in Keynsham

Stage 1: Calibrating the energy model

'Performance gap'; measured **energy** results worse than predicted using the designer's typical schedules, weather data etc: **+107% gas and +46% electric**



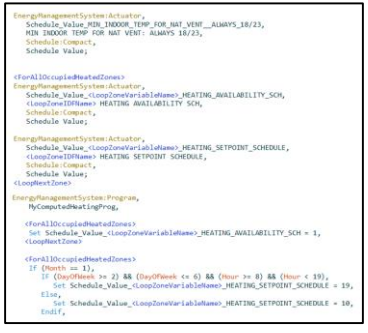
DesignBuilder model

Criteria	Designed (kWh/m²)	Actual (kWh/m²)	Diff (%)
Total Energy (Gas + Elec)	14 + 57	29 + 68	+37%
Heating & Hot Water (Gas+Elec)	13.9+5.0	28.85+0	+53%
Cooling energy (Elec)	0.17	0	NA
Pumps + Mech Vent (Elec)	1.73	9.97	+478%
Int. Lighting (Elec)	5.00	11.13	+123%
Ext. Lighting (Elec)	1.11	0	NA
Small Power (Elec)	16.49	28.89	+75%
Catering (Elec)	0.85	1.60	+89%
Server Elec (Elec)	26.42	15.19	-42%
Lifts (Elec)	0.28	0.72	+159%
PV Generation (Elec)	31.22	30.43	-3%
Net Energy (Gas + Elec)	14 + 26	29 + 38	+67%

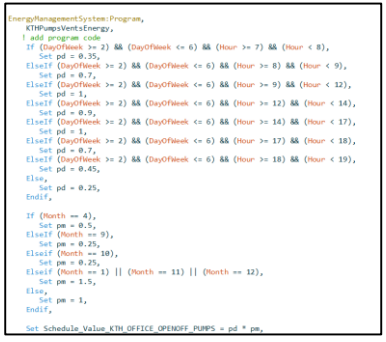
EMS used in the calibration process

EMS used to calibrate the DesignBuilder model more efficiently by modifying key operational data to match the actual building:

Occupancy/lighting patterns/schedules



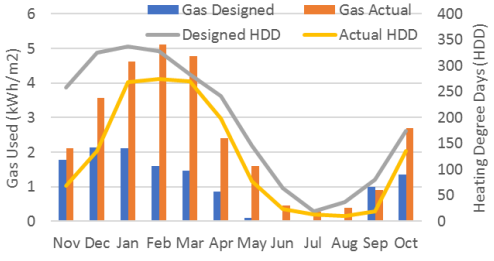
Natvent controls and set points

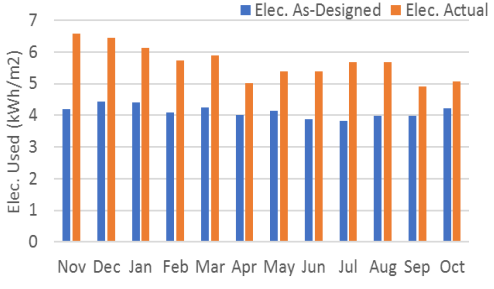


HVAC pump operation

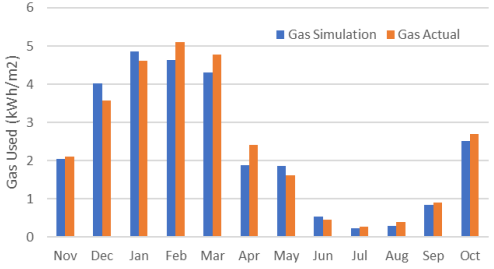
Calibrated model results

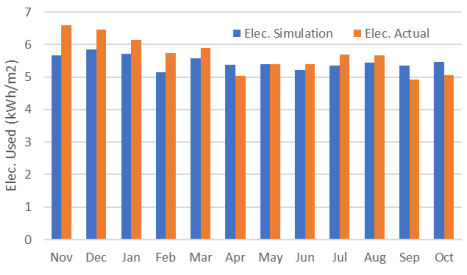
Model calibrated to CV(RSME) and NMBE tolerances of <5% error:





Initial gas & elec results





Calibrated gas & elec results

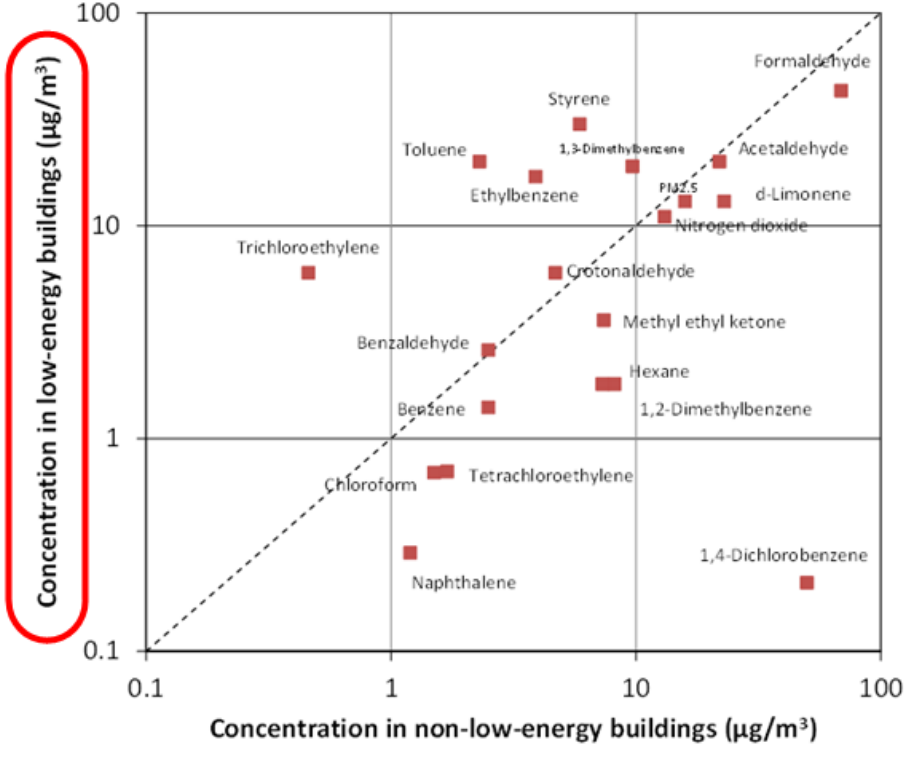
Stage 2: Focus on Health and Wellbeing

The ‘tension’ between low energy and good IAQ

IEA Annex 68 report:

Finds higher pollutant concentrations in low-energy buildings

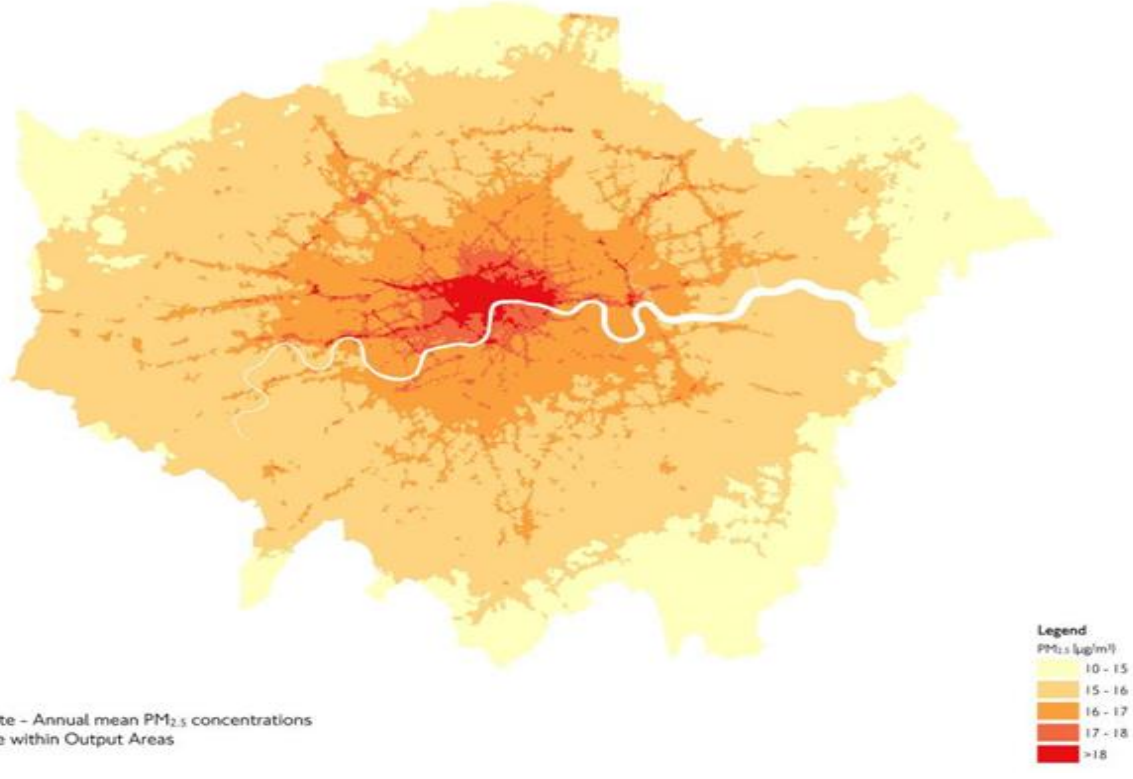
Recommends that key pollutants such as PM2.5 should be measured and kept within limits
…not just CO2!



Health and Wellbeing: PM2.5 concentrations

London PM2.5 values exceed WHO guidelines and sometimes EU limits

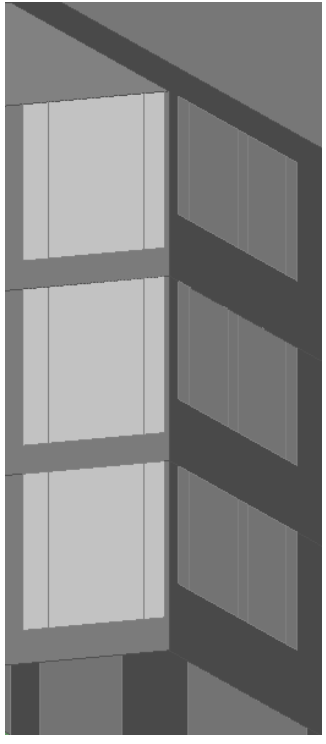
- EU legal limit (annual mean): 25 µg/m³
- WHO guideline limit (annual mean): 10 µg/m³
- **Estimated that difference between EU and WHO limits doubles risk of early death**



2013 LAEI Update - Annual mean $PM_{2.5}$ concentrations based on average within Output Areas

With IAQ in mind: natvent strategy

Vents controlled on CO2 by BMS…CO2 good IAQ proxy but perhaps not in isolation?



Improved IAQ control strategy using EMS

EMS used to import external measured pollutant data, sense both internal CO2 and PM2.5 and modify control strategy, then generate custom output reports

```
EnergyManagementSystem:Program,
   CO2WindowControl,
<ForAllExternalWindows>
   ! on/off control of window opening factor
   If <LoopWindowVariableName>Air_CO2_Concentration > 1500,
      If Schedule_Value_PM25 < 0.04,
         Set Venting_Opening_Factor_<LoopWindowVariableName> = 1,
      Elseif Schedule_Value_PM25 >= 0.04,
         Set Venting_Opening_Factor_<LoopWindowVariableName> = 0,
      Endif,
   Else,
      Set Venting_Opening_Factor_<LoopWindowVariableName> = 0,
   Endif,
<LoopNextWindow>
```

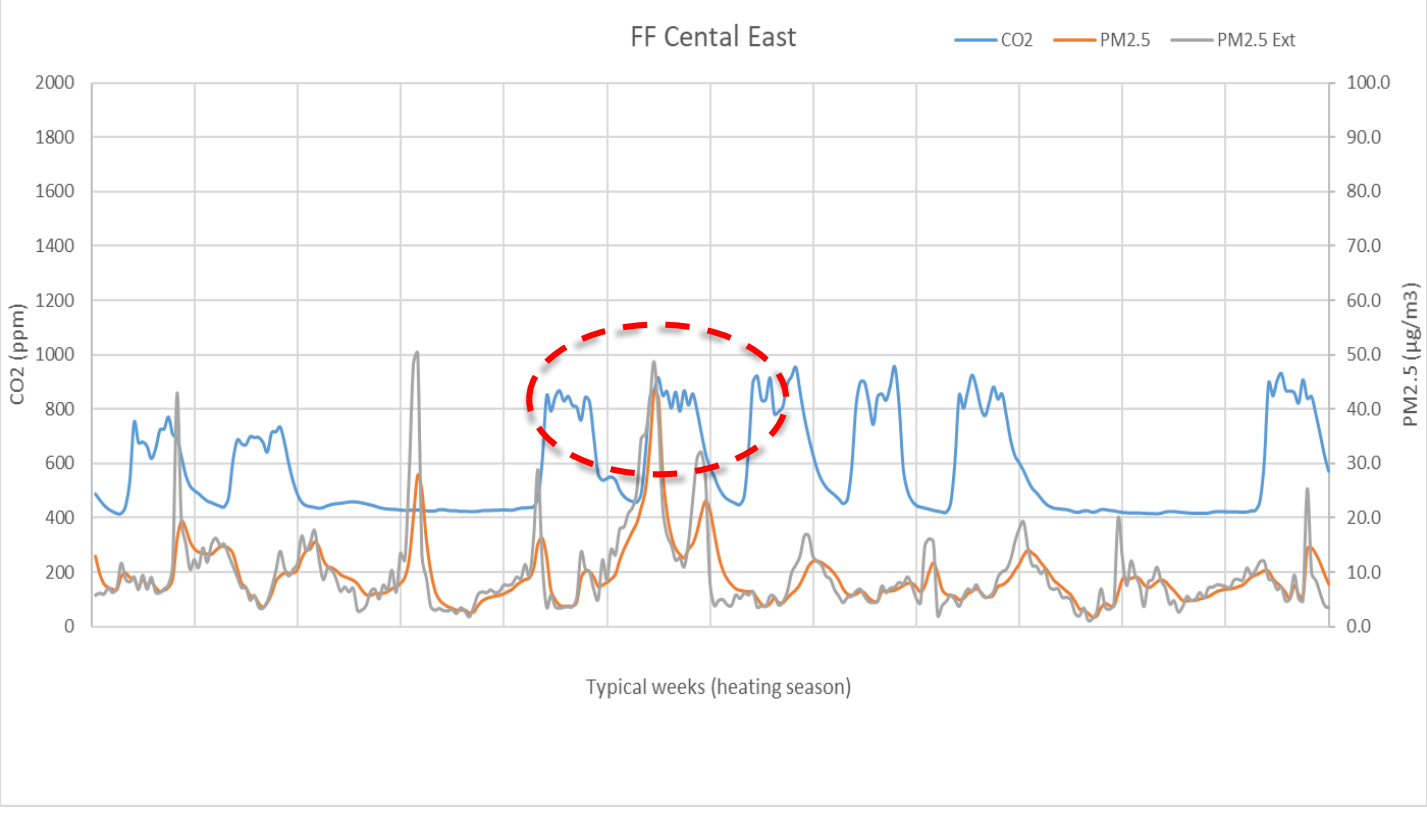
```
Windows>
EnergyManagementSystem:Sensor,
   <LoopWindowVariableName>Air_CO2_Concentration,
   <LoopWindowZoneIDFName>,
   Zone Air CO2 Concentration;

EnergyManagementSystem:Actuator,
   Venting_Opening_Factor_<LoopWindowVariableName>,
   <LoopWindowIDFName>,
   AirFlow Network Window/Door Opening,
   Venting Opening Factor;
<LoopNextWindow>
```

```
! extra outputs for viewing in the results viewer
<If BuildingAttribute HourlyOutput = 1 Then>
Output:Variable, *, Zone Air CO2 Concentration, hourly;
Output:Variable, *, Zone Air Generic Air Contaminant Concentration, hourly;
<Endif>
<If BuildingAttribute TimesteplyOutput = 1 Then>
Output:Variable, *, Zone Air CO2 Concentration, timestep;
Output:Variable, *, Zone Air Generic Air Contaminant Concentration,timestep;
<Endif>
```

IAQ control strategy with high CO2 set point

Standard CO2 control: vents open at 1000 PPM: low CO2, high ACH and PM2.5



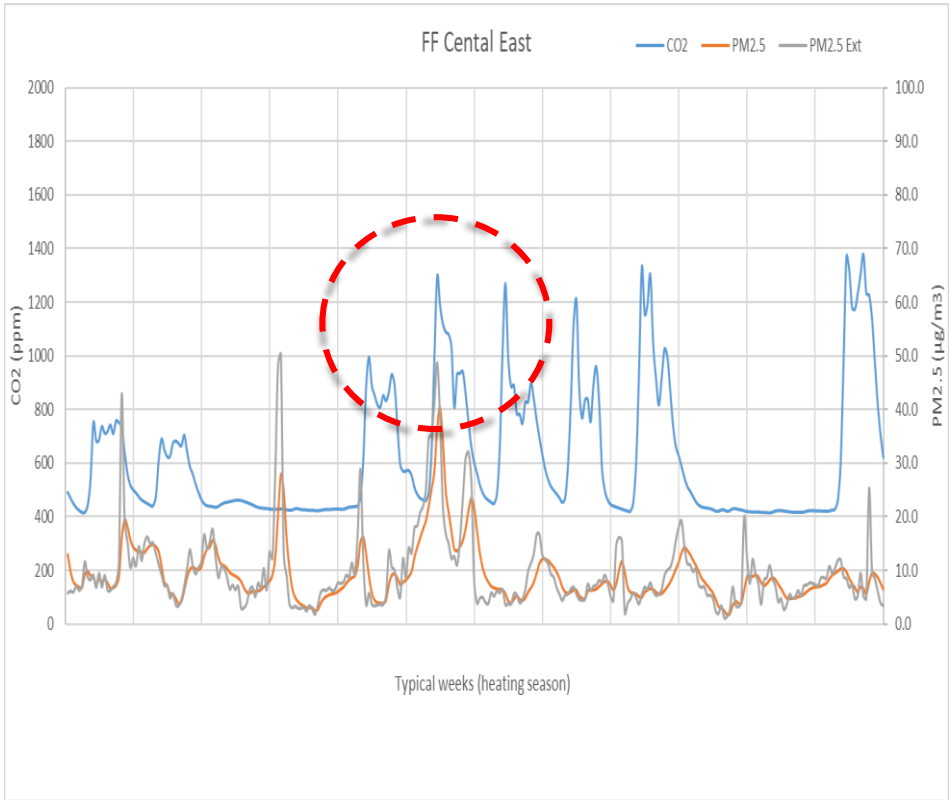
CO_2 set point
1000 ppm

Peak $PM_{2.5}$:
above 40 µg/m³

Energy use
(heating):
145 Wh/m²/day

Holistic IAQ control strategy requires EMS

Revised control strategy: relax CO2 set point, close vents if outdoor PM2.5 high



- CO_2 set point increased to 1500 PPM
- Close vents if outdoor PM2.5 > threshold
- Indoor PM levels maintained below outdoor levels
- Peak $PM_{2.5}$: now below 40 µg/m³
- Energy use (heating): 105 Wh/m²/day
- 28% reduction in heating energy due to relaxation of CO2 limit

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www.DesignBuilder.co.uk for more information

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